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An Internal Validation of the British Army Spatial Disorientation Sortie

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SUMMARY:

Following didactic instruction, most aircrew are able to experience some of the disorienting illusions and limitations of the orientation senses in a variety of ground-based simulation devices such as the Barany chair. In order to reinforce instruction in spatial disorientation (SD) within the environment in which they operate, British Army Air Corps (AAC) helicopter pilots additionally receive an airborne demonstration of the limitations of their orientation senses during initial pilot training and as a quadrennial requirement post-graduation. The sortie syllabus has been previously described [1]. The objective of the assessment presented herein was to determine whether the SD demonstration sortie was a valid method for training aircrew in SD in the AAC. This paper records the results of an anonymous voluntary questionnaire completed by 265 experienced aviators and aviators in training over a two and a half year period immediately following the sortie. The results were entered into a relational database and evaluated by a disinterested party using standard descriptive statistics. The following conclusions were made: the manoeuvres performed in the SD demonstration sortie, and the sortie overall, were extremely effective at demonstrating the limitations of the orientation senses. Furthermore the aviators considered that the sortie greatly enhanced their overall awareness of SD. Thus we may conclude that the sortie satisfies the internal validation process of the Systems Approach to Training.

INTRODUCTION

Spatial disorientation (SD) occurs when a pilot fails to correctly perceive the position, motion, or attitude of his or her aircraft in relationship to the surface of the earth and the gravitational vertical. Such a misperception may have disastrous effects. SD was considered to be a significant factor in 291 (30 percent) Class A through Class C helicopter accidents in the U.S. Army in the 8-year period between 1987 and 1995 (Class A accidents are those exceeding $1 million or resulting in loss of life whereas Class C accidents are those exceeding $12 thousand) [2]. One hundred and ten lives were lost in these accidents, and a monetary cost of nearly $468 million was incurred. It should be remembered that only a relatively small proportion of SD episodes lead to accidents, and that non-mishap incidents also impose operational costs in terms of reduced efficiency or abandonment of the mission. In wartime, the extra pressure placed on the pilot's sensory and cognitive resources heightens the risk of SD. During Operation Desert Shield/Storm, 81 percent of U.S. Army aviation nighttime accidents were ascribed to SD [3].

One of the most important countermeasures to SD is the aviator's awareness of his physiological vulnerability to SD and the operational circumstances and phases of flight in which SD is most likely to occur. Consequently, all military aviators must attend courses of instruction in SD. Despite the regulations that mandate SD training (NATO STANAG 3114 and Air Standard 61/117/E), there is great variability in the quality, quantity, and frequency of this instruction, both between nations and services within a nation [4]. There is, therefore, room for improvement in all aspects of SD training. It has been long accepted that a demonstration of some of the illusions of SD and the limitations of the orientation senses during ground-based training is a vital part of the proper education of aviators. Most student pilots are given instruction during their flight training on how to overcome the effects of SD, but few air services provide a specific SD demonstration sortie to augment ground-based training.

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An in-flight demonstration of SD reinforces aircrew knowledge of the limitations of the orientation senses in flight and enhances aircrew awareness of potentially disorienting situations. In-flight SD training, on the other hand, consists of a series of flight procedures to teach aviators how to cope with disorientating circumstances and illusions (e.g., recovery from unusual attitudes during instrument flight). The teaching of recovery sequences is clearly the responsibility of the Qualified Helicopter Instructor (QHI) in both simulator and actual flying sorties, while an in-flight demonstration of SD, although it could be performed by specially trained QHIs, is best conducted by the Specialist or Consultant in Aviation Medicine (SAM or CAM) who, having performed the ground-based training, is on hand to explain the mechanics of SD. Currently in the AAC and in accordance with Joint Services Publication 318-20502, the SAM or CAM conducts SD training sorties during initial pilot training and on a quadrennial basis thereafter as a refresher.

It was in the pursuance of this philosophy that a specific SD demonstration sortie was developed and has been used by the British Army for over the last 18 years. The sortie demonstrates the limitations of their orientation senses to aviators during helicopter manoeuvres in flight. The demonstration cannot be conducted in a motion-based simulator such as the ASDD, which simulate SD in fixed wing aircraft relatively well, because such devices cannot create the appropriate rotary-wing acceleration environment to induce an effective result [5]. The British Army SD sortie has been previously described in detail, and its efficacy both in training aircrew and in preventing SD related accidents discussed [1].

In accordance with current British Army doctrine (Army Code 70670 PAM 4), the systems approach to training (SAT) requires organisations to monitor the efficacy and validity of training. Validation of training is the process of determining firstly, whether training is achieving specified training objectives (internal validation) and secondly, whether the training objectives reflect the requirements of "the job" (external validation). Continuous and systematic validation of training is necessary to establish that training is effective and to ensure that it is adjusted to meet changes in job requirements. Such changes may be caused by the introduction of new or modified equipment, by new techniques, or by the restructuring of the job to include new tasks or exclude old ones. Once the decision to train has been taken, consideration of the most cost-effective means of carrying out the training is necessary. Assessment of the effectiveness of training is a principal concern of trainers. Measures of efficiency on the other hand are the concern of others besides the trainer and are likely to involve consideration of factors beyond the competence of those immediately concerned with training. It must be stressed that this process is particularly important in the prevailing climate of fiscal constraint and limited resources.

Validation allows training programmes to meet changes in the job requirements. This is extremely important in aviation. Military rotary-wing aircraft are becoming more diverse and more sophisticated. In the military field, despite advances in control and instrument technology, the aircrew certainly do not have a lesser number of tasks, but these tasks have significantly changed in nature over the years. These tenets must drive the training requirement. As far as training in SD is concerned it is reasonable to make the following statements with respect to the SAT process: 1). The "job" may be generally defined as the optimal performance of the pilot in his duties, and specifically as the prevention and/or control of the hazard of SD, 2). Such is the nature of SD that aeromedical professionals may be concerned both with the delivery of training and the measurement of both its effectiveness and efficiency.

The metrics that may be used to determine the effectiveness of SD demonstration and training are both difficult to define and different studies have used different outcomes. There would be merit in standardising these aspects between services and nations. The extremes of those that have been used are from "user satisfaction to training" on the "soft end" of the spectrum, to a demonstrated reduction in the SD accident rate at the "hard" end. The former can be regarded as a measure of internal validation, whilst the latter goes much of the way to being an external validation assessment. However, even the latter is fraught with problems because of the differences in both the diagnosis (because there are often no witnesses to the catastrophic SD accident) and subsequent classification of the SD accident.

The only known type of SD training for which external validation has been applied is the rotary-wing SD demonstration sortie in the British Army. An objective analysis of this demonstration assessed the benefits in terms of operational outcome - its effect on lowering the SD accident rate in the AAC [6]. However, although

we have reasonable external validation, no internal validation has recently been performed. This paper describes an internal validation assessment of the SD sortie by AAC personnel. During the study, the opportunity was also taken to gain subjective opinions on the current standard of SD training.

METHODS

In order to internally validate the current SD sortie demonstration, a research protocol was developed at The School of Army Aviation, Middle Wallop. The sortie was demonstrated to a cross section of Army aviators from the novice student to senior instructor pilots (hereafter referred to as participants). Two hundred and sixty five individuals experienced the sortie over a two and one half year period and gave their opinions via post-flight questionnaires. The Army personnel were from one of two groups: trained aviators and student pilots. All participants voluntarily agreed to the anonymous questionnaire.

In the British Army, the Consultant or Specialist in Aviation Medicine who is a pilot-physician both flies and conducts the sortie from a standardized syllabus [1]. The Gazelle helicopter was used in these demonstration sorties and was commanded and flown by a SAM or CAM from the pilot's seat. Participants (either two or three per sortie) occupied the cabin seats facing forward. They were fully briefed on the nature of the sortie, in particular, that the manoeuvres were not violent or nauseagenic; that the aim was to augment their ground training by demonstrating the limitations of perception; and that they were not being trained in how to overcome SD. Following a transit to the demonstration area, a series of forward flight and hover manoeuvres was conducted. In turn, each of the participants was asked to sit free of the airframe structures, note the aircraft's initial flight parameters, close their eyes, lower their dark visor (to limit cues from ambient sunlight), and, as the participant for that manoeuvre, give a running commentary on their perception of the aircraft's flight path. In this way, the participant (subject) was deprived of vision (the most important of the orientation senses) so that the limitations, particularly the unreliability of the non-visual orientation senses, could be demonstrated. The other participants (observers) were asked to observe but not comment until after the manoeuvre was complete. The SAM then debriefed the manoeuvre. All participants experienced at least one manoeuvre in each of the forward flight and hover groups as described below:

- **Level turn:**

Straight and level flight is established at 90 knots. After 10 seconds, a gently increasing (supra-threshold) roll to 30-degree angle of bank is commenced while maintaining airspeed and altitude. This is stabilized and, on completion of a turn between 180 degrees and 360 degrees, the aircraft is rolled wings level again at a supra-threshold rate. The subject is told to open his eyes once he considers that he is again straight and level. Debriefing points: the onset of the roll is normally detected, but as the semicircular canal response decays, a false sensation of a return to straight and level flight is perceived. As the roll to level flight is made, a sensation of turning in the opposite direction is perceived. The limitations of semicircular canal physiology are discussed.

- **Straight and level:**

Straight and level flight is established at 90 knots and one of the other participants is asked to close his eyes. The aircraft is flown with no alteration of altitude, heading, or airspeed. Debriefing points: because of small aircraft movements from turbulence and the aerodynamic response of the helicopter which stimulate the kinaesthetic and/or vestibular apparatus above their threshold, students perceive climb, descents, or turns in unpredictable and varying amounts. The erroneous sensations produced by brief stimulation of the kinaesthetic receptors and vestibular apparatus is discussed.

- **Straight and level deceleration to a free hover:**

Straight and level flight is established at 90 knots into wind, and once the subject closes his eyes, the helicopter is slowed within 30-40 seconds to a free air hover with no change of heading or altitude. Debriefing points: the nose-up pitch associated with the attitude change in the final stages of slowing the aircraft usually convinces the subject that a climb is taking place. In addition, a turn is often falsely perceived when balance variations are made to keep straight. The absence of accurate physiological perception of airspeed is discussed.

- **Inadvertent descent:**

This manoeuvre is commenced from about 500 ft above ground level (AGL). Straight and level flight is established at 90 knots, and the subject closes his eyes. While initiating a descent at below 500 feet per minute, a series of turns is commenced. When the aircraft is established in contour flight below 50 feet AGL, the subject is asked to report his heading, height, and airspeed and then open his eyes. Debriefing points: the descent is not usually perceived, and due to the proximity of the ground at the end of the manoeuvre, this demonstration forcibly and convincingly demonstrates the danger of inadvertent descent.

- **Hover:**

As the helicopter has a unique ability to accelerate about, as well as along orthogonal axes, the final series of demonstrations starts from a 5- or 6-foot hover. In turn, the participants are exposed to a variety of linear and rotational movements while maintaining hover height. The SAM keeps prompting the subject for a running commentary (to occupy channels of attention) and so exacerbates the onset of SD. Within these exercises, various manoeuvres are hidden so that when the subject opens his eyes, a dramatic end point is evident: climbing backwards at 10-15 knots; landing without the subject realizing it; a gentle transition to forward flight.

After the sortie, participants were asked to complete voluntary and anonymous questionnaires. Each questionnaire contained five questions requiring the participant to score each demonstration as either a subject or observer on a scale of 1-10 (1=extremely poor, 5=adequate, 10=extremely good). An additional question was asked, using the same scale, as to the participant's overall view of the sortie's effectiveness. Additionally, each participant was asked to determine how his or her individual awareness of SD had changed on a scale of 1-13 (1="I know nothing about SD", 7="No change", 13= "I am totally enlightened"). A final area was available for individuals to comment on the experience.

RESULTS

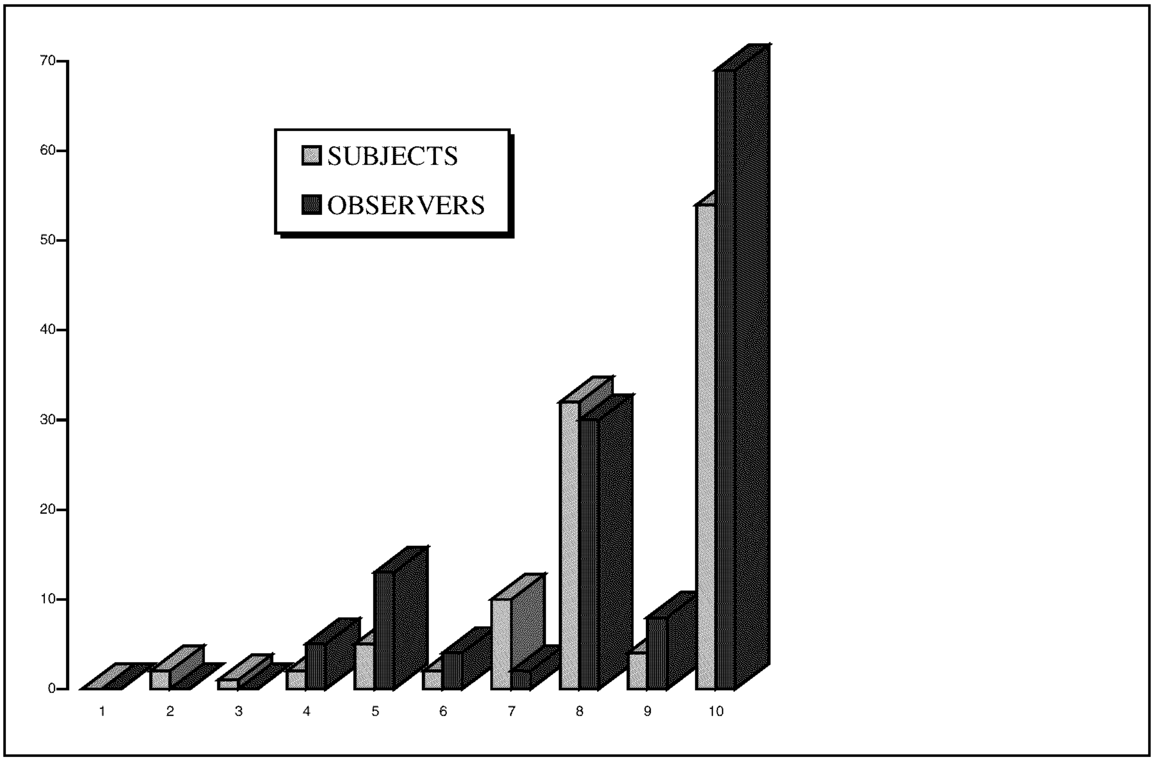
The results of this evaluation are based upon analysis of the post flight questionnaire data. Some additional comments from those experiencing the SD demonstration sortie are also recorded.

Assessment of the SD sortie manoeuvres

Participants were asked to rate each manoeuvre and the sortie overall, on its ability to convince them that their non-visual senses were unable to give them accurate orientation information. Out of the 265 questionnaires distributed, 265 were returned (100%). The student pilot participants numbered 167 (63%) while the refresher participants numbered 98 (37%).

The questions posed are reproduced in the figures annotated below together with some additional comments on the manoeuvres. The distribution of ratings for the individual manoeuvres and the sortie overall are presented in figures 1 to 7. All graphs represent combined data from the initial training participants and the refresher training participants, however, individual breakdowns are annotated in the legends accompanying each graph. Additionally, the total percentage of the subjects who felt that the demonstrations as well as the sortie *in toto* were at least adequate or better are annotated.

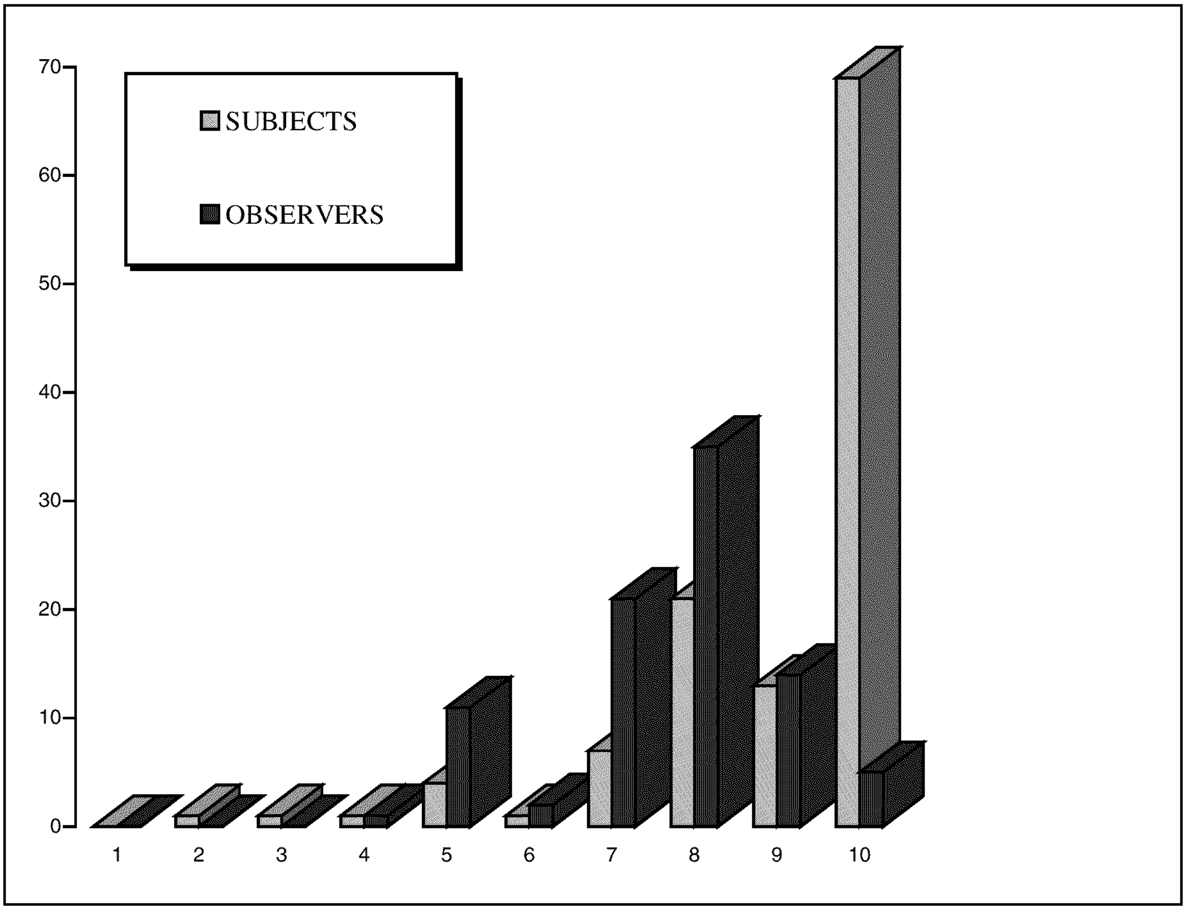
FIGURE 1: 360-DEGREE LEVEL TURN MANOEUVRE:



KEY: 1 = Extremely Poor 5 = Adequate 10 = Extremely Good COMBINED DATA			Break down of Initial **(I)** vs. Refresher **(R)** Participants			
STATISTICS	SUBJECTS	OBSERVERS	I SUB	I OBS	R SUB	R OBS
N=	112	149	69	98	43	51
Mean =	8.52	8.40	8.18	8.2	8.4	8.5
STDEV =	1.86	1.83	1.95	1.87	1.78	1.77
Median =	9	9	8	9	9	8
Mode =	10	10	10	10	10	10
Range	10-2	10-4	2-10	4-10	3-10	4-10
Question: "How successful would you rate the 360 degree level turn manoeuvre in its ability to convince you that it is difficult for you to sense motion and attitude without aircraft instruments?"						

Figure 1 demonstrates that of the 261 participants that experienced this manoeuvre, approximately 96% rated it as at least adequate in demonstrating SD and that greater than 89% of the participants rated it above average. Of note there was no statistical difference between the Initial and Refresher participants in their overall rating of the manoeuvre.

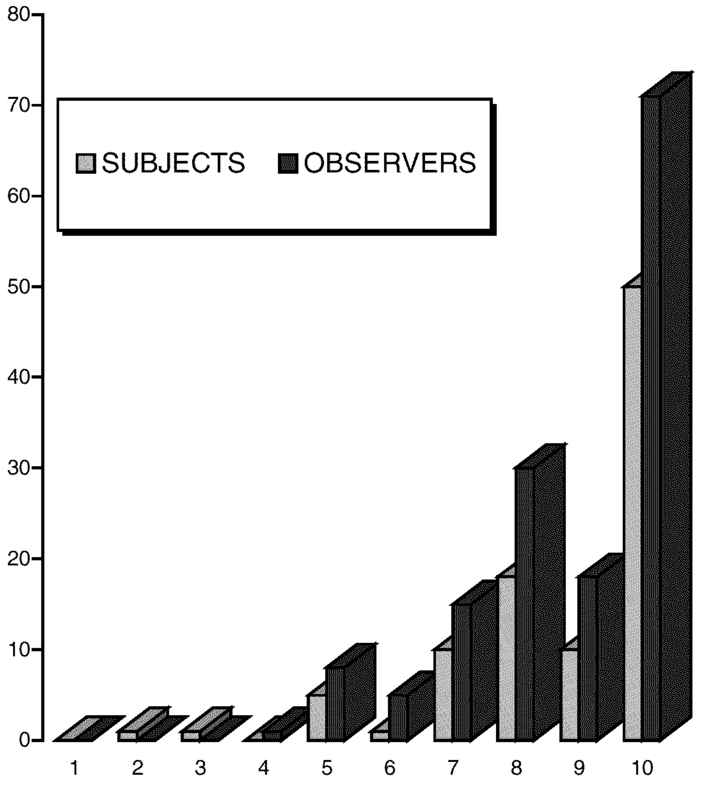
FIGURE 2: STRAIGHT AND LEVEL MANOEUVRE:



KEY: 1 = Extremely Poor 5 = Adequate 10 = Extremely Good			Break down of Initial (**I**) vs. Refresher (**R**) Participants			
COMBINED DATA						
STATISTICS	SUBJECTS	OBSERVERS	I SUB	I OBS	R SUB	R OBS
N=	117	143	68	100	49	43
Mean =	9.0	8.5	8.55	8.55	9.0	8.0
STDEV =	1.6	1.6	1.6	1.4	1.41	1.83
Median =	10	9	9	8	10	8
Mode =	10	8	10	8	10	8
Range	10-2	10-4	10-2	10-4	10-4	10-4
Question: "How successful would you rate the straight and level manoeuvre in its ability to convince you that random motion experienced in flight (e.g., turbulence) can give you the wrong information?"						

Figure 2 demonstrates that of the 260 participants that experienced this manoeuvre, approximately 98% rated it as at least adequate in demonstrating SD and that greater than 93% of the participants rated it above average. Of note there was no statistical difference between the Initial and Refresher participants in their overall rating of the manoeuvre.

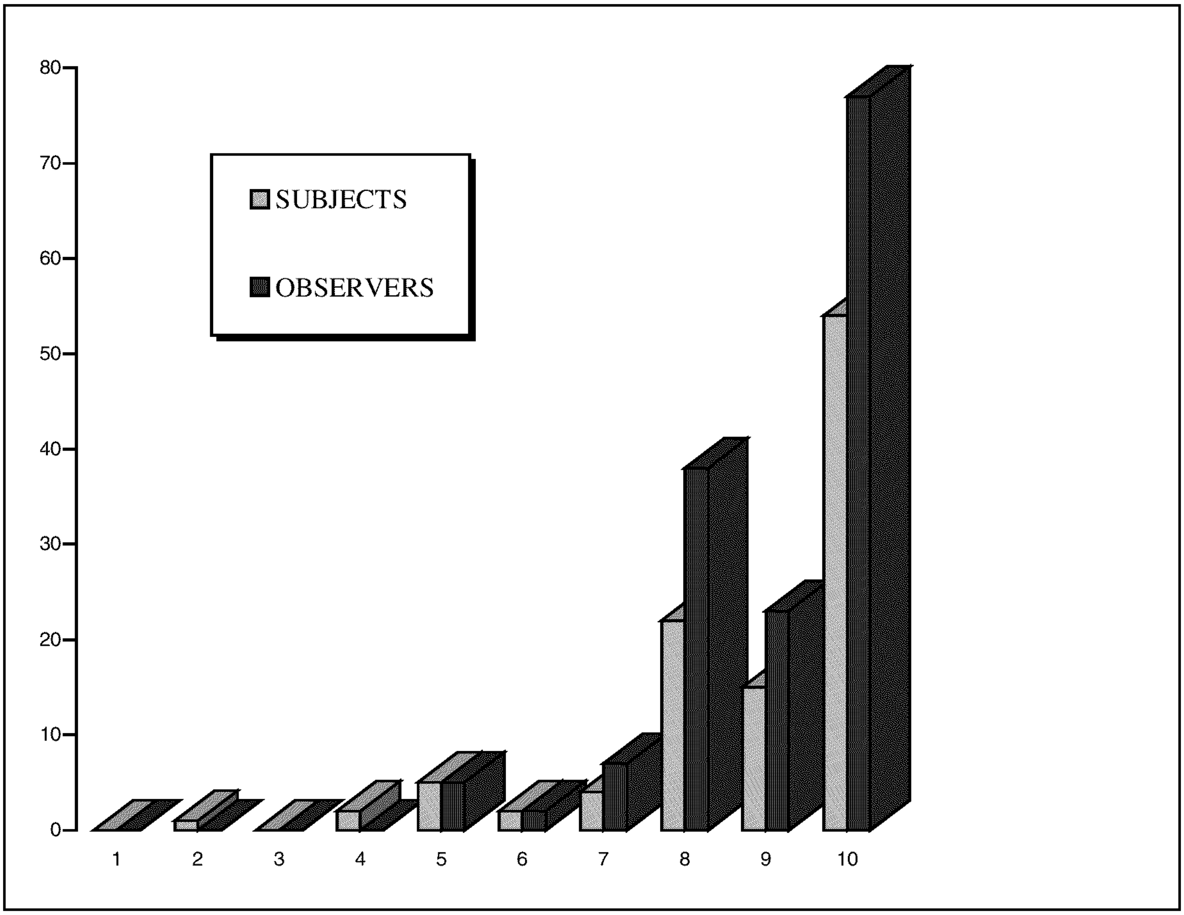
FIGURE 3: DECELERATION TO A FREE AIR HOVER MANOEUVRE:



KEY: 1 = Extremely Poor 5 = Adequate 10 = Extremely Good			Break down of Initial **(I)** vs. Refresher **(R)** Participants			
COMBINED DATA						
STATISTICS	SUBJECTS	OBSERVERS	I SUB	I OBS	R SUB	R OBS
N=	97	147	63	105	34	42
Mean =	8.71	8.76	8.8	8.5	8.7	8.6
STDEV =	1.75	1.50	1.53	1.47	1.8	1.5
Median =	10	9	9	9	9	9
Mode =	10	10	10	10	10	10
Range	10-2	10-4	10-2	10-5	10-4	10-5
Question: "How successful would you rate the deceleration manoeuvre in its **combined** ability to demonstrate both the illusion of climbing when the aircraft is pitched nose up, and the inability to accurately detect airspeed changes without reference to flight instruments?"						

Figure 3 demonstrates that of the 244 participants that experienced this manoeuvre, approximately 99% rated it as at least adequate in demonstrating SD and that greater than 93% of the participants rated it above average. Of note there was no statistical difference between the Initial and Refresher participants in their overall rating of the manoeuvre.

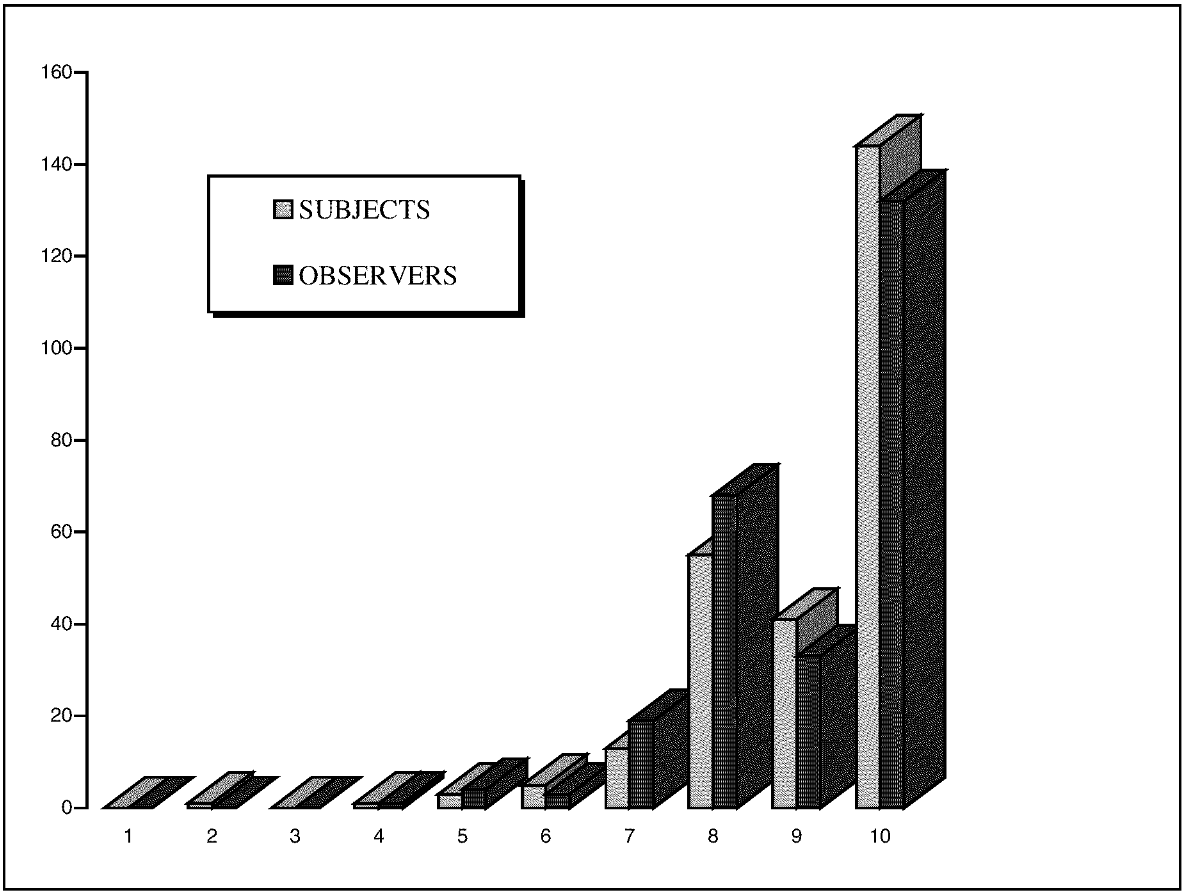
FIGURE 4: INADVERTENT DESCENT MANOEUVRE:



KEY: 1 = Extremely Poor 5 = Adequate 10 = Extremely Good			Break down of Initial (**I**) vs. Refresher (**R**) Participants			
COMBINED DATA						
STATISTICS	SUBJECTS	OBSERVERS	I SUB	I OBS	R SUB	R OBS
N=	105	152	62	105	43	47
Mean =	8.81	9.0	8.8	8.64	8.63	9.0
STDEV =	1.7	1.26	1.37	1.33	1.37	1.25
Median =	10	10	9	9	9	8
Mode =	10	10	10	10	10	10
Range	10-2	10-5	10-2	10-4	10-5	10-5
Question: "How successful would you rate the inadvertent descent manoeuvre in its ability to convince you that it is difficult to accurately sense the position, motion, and attitude of the aircraft when close to the ground in conditions of poor visibility?"						

Figure 4 demonstrates that of the 262 participants that experienced this manoeuvre, approximately 99% rated it as at least adequate in demonstrating SD and that greater than 95% of the participants rated it above average. Of note there was no statistical difference between the Initial and Refresher participants in their overall rating of the manoeuvre.

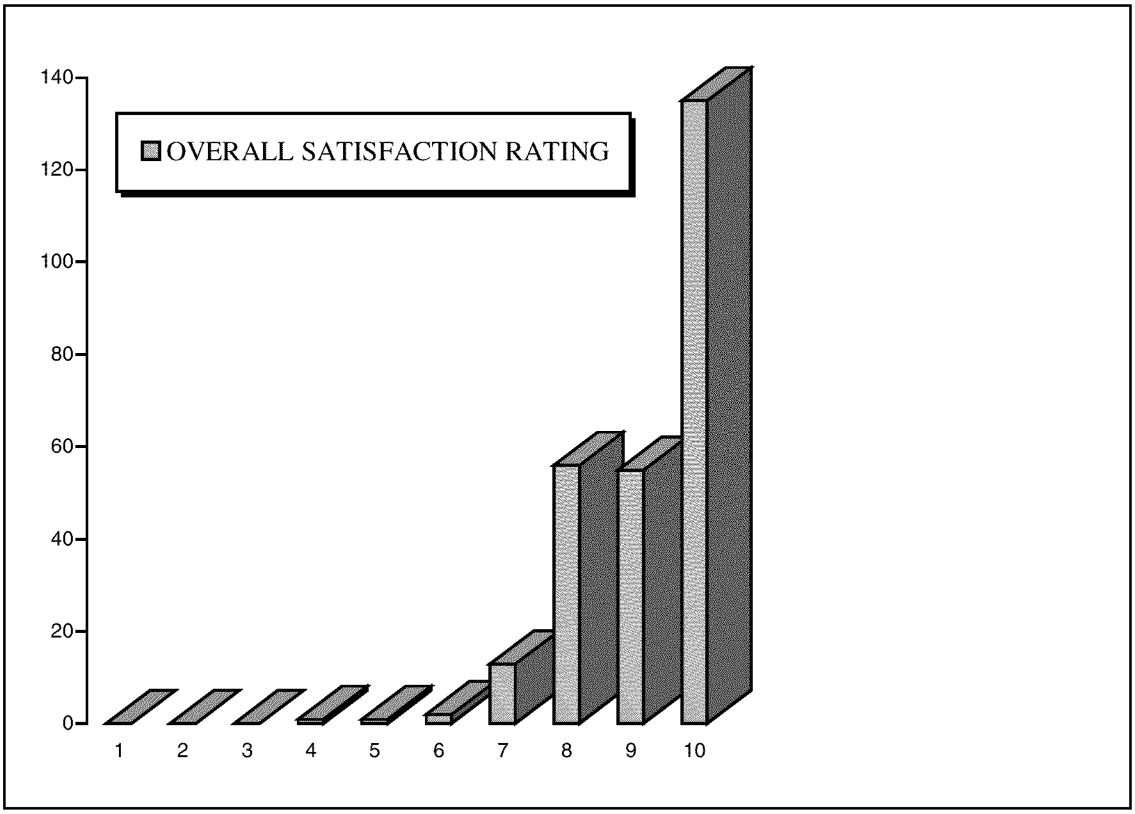
FIGURE 5: HOVER MANOEUVRES:



KEY: 1 = Extremely Poor 5 = Adequate 10 = Extremely Good COMBINED DATA			Break down of Initial (**I**) vs. Refresher (**R**) Participants			
STATISTICS	SUBJECTS	OBSERVERS	I SUB	I OBS	R SUB	R OBS
N=	263	260	168	166	95	94
Mean =	9.1	9.0	8.95	8.91	9.0	8.8
STDEV =	1.26	1.23	1.4	1.2	1.4	1.25
Median =	10	10	10	9	9	9
Mode =	10	10	10	10	10	10
Range	10-2	10-4	10-4	10-4	10-2	10-5
Question: "How successful would you rate the hover demonstrations in their ability to convince you that it is difficult to accurately sense the position, motion, and attitude of the aircraft when close to the ground in conditions of poor visibility?"						

Figure 5 demonstrates that of the 523 participants that experienced this manoeuvre (almost 100% experienced the manoeuvre as both a Subject and an Observer), greater than 99% rated it as above average in demonstrating SD. Of note there was no statistical difference between the Initial and Refresher participants in their overall rating of the manoeuvre.

FIGURE 6: THE OVERALL CUSTOMER SATISFACTION WITH THE SORTIE:



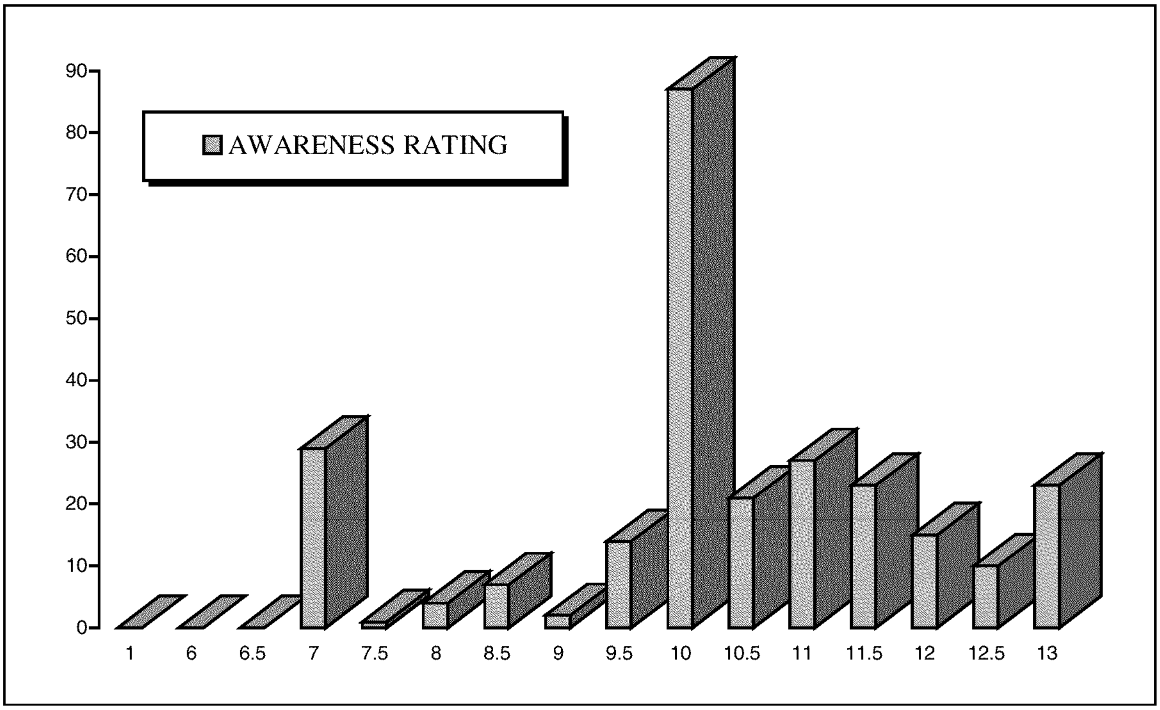
KEY 10 – Extremely Satisfied 5 - Adequately Satisfied 1 - Not Satisfied	INITIAL TRAINING	REFRESHER
Participants N = 265	167	98
Mean = 9.14	9.1	9.0
STDEV = 1.06	0.94	1.22
Median = 10	9	9
Mode = 10	10	10
Range = 10-4	10-5	10-4
Question: "Overall, how well did this demonstration sortie show the limitations of the orientation senses in flight?"		

Figure 6 demonstrates that of the 265 participants that experienced this SD Sortie, greater than 99% rated it as above average in demonstrating SD. Of note there was no statistical difference between the Initial and Refresher participants in their overall rating of the manoeuvre.

Post Sortie SD Awareness.

Participants were asked to rate their awareness of the limitations of the orientation senses in flight compared to their previous knowledge. The distribution of responses to this question is shown in figure 7. It should be noted that 100% of the respondents considered that the sortie felt that they were at least as aware post sortie, but that approximately 90% felt that they were more aware post sortie.

FIGURE 7: SD AWARENESS POST SORTIE:



KEY 13 – "Totally Enlightened" 7 - "The Same as Before" 1 - "I Know Nothing About SD"	INITIAL	REFRESHER
Participants N = 265	167	98
Mean = 10.3	10.5	9.6
STDEV = 1.63	1.48	1.67
Median = 10	10	10
Mode = 10	10	10
Range = 13-7	13-7	13-7
Question: "Compared with your awareness of the limitations of the orientation senses in flight **before** the sortie, how would you rate your knowledge now?"		

Individual comments assessing the SD training sortie demonstration.

90 individuals (34%) made comments regarding the sortie. All comments were supportive. A list of the most common and notable comments is as follows.

- "The Sortie was good/great/excellent/worthwhile/highly useful, etc" – 47 individuals made this type of comment.
- "The Sortie was useful in reminding us to fly with our instruments not by the seat of our pants/senses" - 8 individuals made this comment.
- "As an Instructor I feel this is a crucial training program for not only the novice student but also the experienced QHI with thousands of hours in the air" - 3 participants made this comment.
- "SD cannot be fully understood without this demonstration" - 1 participant.
- "As a QHI, I am sure that this sortie can and does save pilots and airframes" - 1 participant.

DISCUSSION

This assessment set out to determine the internal validity via the SAT process of the Army SD demonstration sortie and whether it is an effective adjunct to training aircrew in SD. The cross-section of aviators included a number of very experienced instructor pilots whose comments were most valuable, as they are well positioned to influence the executive authorities on training issues. It may be inferred from individual comments recorded by the study participants that they regard SD as a significant hazard associated with Army helicopter operations. Response data indicated that the quality of SD training during initial and refresher training is greatly enhanced by the sortie. The manoeuvres performed in the SD demonstration sortie, and the sortie overall, were extremely effective at demonstrating the limitations of the orientation senses. Furthermore, the sortie was given a significantly high rating via individual comments in its effectiveness to train aviators in SD than other available methods (didactic training).

The SD sortie has been previously externally validated in that the SD accident rate for the 10 years before the demonstration was introduced (2.04 accidents per 100,000 flying hours {1971 – 1982}) was compared with a similar period following its introduction (0.57 accidents per 100,000 flying hours {1983-1993}) [2,7]. The statistical analysis inferred a period effect of a highly significant reduction in the SD accidents rates since the sortie has been introduced. There are confounding factors in this analysis. Some factors will have tended to reduce the orientation error accident rate, e.g., the introduction to service of aircraft with automatic flight control systems and stability augmentation in the late 1970s; the installation of additional aircraft flight instruments (e.g., radar altimeters) in the early 1980s; the phasing out of predominantly single pilot operations in the mid 1980s and subsequent introduction of 2 qualified pilot crews for most sorties in the late 1980s; and a reclassification of the accidents to exclude the lesser damaged airframe in 1991. A counterbalancing factor that has tended to increase the orientation error accident rate is the much greater use of night vision goggles since the mid 1980s.

Notwithstanding these arguments, it is reasonable to assert that the SD demonstration sortie has contributed to reducing the accident rate in which SD is involved. It should be noted that both the U.S. Army and the Canadian Air Force have both recently added this sortie to their initial flight-training syllabus and it is hoped that these nations will carry out similar analysis in the future.

The purpose of this study was, however, to provide a measure of internal validation using the SAT Process. The results presented suggest that the SD sortie satisfies those requirements. It is evident that the participants in the study responded that not only were the individual demonstrations and the sortie overall satisfactory to excellent, but approximately 90% also noted that they were more aware of SD secondary to this training.

In this era of budgetary restraints for military training, it should also be noted that any additional flight training bears a cost both in terms of money and time spent training. In the Army, the Gazelle is used to fly the sortie. Using 1996 real military operating costs, a charge of approximately £90 per student has been calculated. The total cost over nearly 18 years of this training has been approximately £200,000 or an average annual sum of just over £12,000. The overall figure is a very small fraction of the replacement cost of even the least expensive in-service Army helicopter. The time spent performing the demonstrations to a class can be minimized by doing

rotor-turning crew changes. In the Army, class sizes are usually 12 students; so 4 sorties can be completed within approximately 2 hours [1]. It is stressed that this demonstration does not seek to train the aviator in how to deal with SD once it has occurred; that is the responsibility of the QHI.

Although, the assessment of internal validity via the SAT Process was concluded to be successful, as Army mission requirements change and as the Army modernizes its rotary-wing fleet (for example Apache AH1), the Aviation Medicine Specialist must be vigilant and closely monitor the SD accident and incident rate to determine if syllabus changes are required.

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